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THE EUROPEAN ELM SCALE IN THE WEST.[1]

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INTRODUCTION.

The European elm scale, *Gossyparia spuria* (Modeer), has long been known in Europe and the Eastern United States as a serious enemy of the elm. It was first discovered in the West in 1893, when E. M. Ehrhorn found it infesting elms on the Stanford University campus, Palo Alto, Calif. Prompt measures of eradication were attempted, but were not entirely successful. Since that time it has spread from this or other sources until it is now quite widely distributed throughout the West. It is becoming of considerable importance as a shade-tree pest owing to its distribution and to its particularly aggressive habits in newly infested localities.

IMPORTANCE.

The elm is probably the most popular shade tree in America. It attains good size, produces a luxurious amount of green foliage, and is planted throughout the United States and elsewhere in dooryards, along streets, and in parks for shade and ornament. In the East

[1] Acknowledgments are due to Dr. A. D. Hopkins, Forest Entomologist; H. E. Burke, Specialist in Forest Entomology; Harold Morrison, Coccidologist; and others, for helpful suggestions and observations; to W. S. Fisher, Specialist in Forest Coleoptera, for identification of the coccinellid predators; to S. B. Doten, Director and Entomologist of the Nevada Agricultural Experiment Station, and to Frank N. Wallace, State Entomologist of Indiana, for the use of a number of illustrations used in this publication.

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the native elm also produces wood which is particularly valuable in the making of vehicles, baskets, crating, etc.

The European elm scale infests all species of elm, having become such a very disagreeable and harmful pest that in many eastern localities these trees are no longer recommended for planting. In the West the scale insect is not so widely distributed, nor are many of its eastern associates present, so that in spite of the elm scale the tree is still recognized as one of the best for shade.

Fortunately, the scale in America infests only elms and is not a pest on fruit or other shade trees, as are many of the aggressive scale insects.

HISTORY.

This insect was first noted in the United States in 1884, when Charles Fremd found it infesting elm trees in his nursery at Rye, Westchester County, N. Y. It had undoubtedly been imported from Europe, where it has been known for nearly 200 years. It was next reported by Professor Comstock from New York City, where he had found it rather abundant in the winter of 1886–7. A few months later John G. Jack sent specimens to the United States Bureau of Entomology from slippery elm growing at Cambridge, Mass. In 1888 it was found at Washington, D. C., infesting elms on the grounds of the Department of Agriculture and also in two localities on the streets of the city.

Up to this time it had not been positively identified, but the next year Dr. L. O. Howard made a thorough study of the insect and identified it as the European elm scale (*10*).[3]

A few years later this scale insect was found to have invaded the western part of the United States. In 1894, Alexander Craw (*2*), of the California State Board of Horticulture, reported that during the previous season E. M. Ehrhorn had noted the European elm scale upon elms at Stanford University, California. The next year Mr. Hillman, entomologist of Nevada, reported it from Reno, Nev., and in 1906 A. L. Melander (*16*), entomologist of Washington, stated that it had been in Spokane, Wash., for several years.

From time to time it has been reported from one State or another until it is now known to occur in 27 States besides the District of Columbia.

SYNONYMY.

As early as 1738 this scale was known in Europe, at which time Reaumur (*18*) figured the female in all its stages and gave its natural history, but failed to give it a name except that of "progallinsecte" of the elm.

The first name given to it was *Coccus ulmi* by Linnaeus (*14, p. 265*) in 1761. In 1875, Signoret (*19, p. 21*) removed this insect from the genus Coccus and erected a new genus, Gossyparia, with *ulmi* as the type. The specific name *ulmi* was retained until recently, when it was discovered that it rightfully belonged to another insect named *Coccus ulmi* Linnaeus (*13, p. 455*) in 1758, since removed to the genus Lepidosaphes. Consequently the next specific name used for the European elm scale, *spurius*, applied to it in 1778 by Modeer

[3] Numbers in parentheses (*italic*) refer to Literature cited, p. 18.

(*17*), was adopted, so that now the proper name is considered by most entomologists to be *Gossyparia spuria* (Modeer).

The latest change has been by the European coccidologist Lindinger (*12, p. 331*), who put this species into Eriococcus, where the writer considers that it rightfully belongs. No move has been made toward accepting this name in the United States so far, however, so that the writer does not feel inclined to use it in this paper.

The two genera, Gossyparia and Eriococcus, are separable only from the fact that the adult female of the former secrets a semicocoon, while the latter entirely covers itself with a cottony cocoon. This means that *Gossyparia spuria* lacks wax-secreting glands on the dorsum, which can hardly be considered a generic character. If the name *Ericoccus spurius* is accepted, then the genus Gossyparia will become a synonym of Eriococcus, as *spuria* is the type of that genus.

From time to time this insect has been referred to under the following names: *Coccus ulmi*, *C. spurius*, *C. laniger*, *C. gramuntii*, *Chermes ulmi*, *Nidularia lanigera*, *N. gramuntii*, *Gossyparia ulmi*, *G. gramuntii*, *G. spuria*, and finally *Eriococcus spurius*.

DISTRIBUTION AND SPREAD.

DISTRIBUTION.

This common pest is widely distributed, not only in North America but also in Europe, where it reaches from Spain to Turkey and as far north as Norway. Kuwana (*11*) has also reported it from the province of Shinano, Japan. The writer has seen specimens from there collected by Mr. Kuwana, however, which undoubtedly are not *Gossyparia spuria*, but are some rather closely related species. The writer is informed that Mr. Kuwana is now of the same opinion. Instead of being encircled with fringe of wax, the body of the mature female is entirely covered with it—a character which should place this species in the genus Eriococcus.

In America the scale is found both in Canada, where it has been reported from the provinces of Ontario and Quebec, and in the United States, where it occurs in 27 States and the District of Columbia. It is still spreading, for occasionally a new State is added to the list. The scale is known to occur in the following Eastern, Central, and Southern States: Maine, New Hamshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Maryland, District of Columbia, Virginia, West Virginia, Ohio, Michigan, Wisconsin, Indiana, Illinois, Iowa, Missouri, Alabama and Louisiana.

In the west the scale occurs in the following States: Colorado, Utah, Nevada, Idaho, Washington, and California. (Fig. 1.) Its distribution in these States is more or less limited. In Colorado, C. P. Gillette, State entomologist, reports that it has been doing damage for some time in the city of Denver. George M. List (*15*), his chief deputy, has since reported it from Golden and from near Fruita, Mesa County. W. W. Henderson, entomologist of the Utah Agricultural Experiment Station, states that to his personal knowledge it exists in isolated places about 100 miles north and south

of Salt Lake City and in the region between these two extremes, where it occasionally does severe damage. In Nevada it is confined to a limited area in the west-central part of the State, extending from Carson City to Reno, according to S. B. Doten (*3, 5*), director of the Nevada Agricultural Experiment Station, and from the writer's personal observations. A. L. Melander (*16*), entomologist of the Washington Agricultural Experiment Station, reports that he has not found it anywhere in the State of Washington, except at Spokane, where it has been for 15 years or more. The files of the Bureau of Entomology also contain records of this insect occurring at Coeur d' Alene and Boise, Idaho.

In California, the insect is somewhat more widespread, occuring in a number of localities in the northern and central portions of the State. It has been found in or near the following towns: Ukiah, San Rafael, Colusa, Woodland, Davis, Sacramento, Stockton, Modesto, Oakdale, Woodside, Redwood City, Palo Alto, Stanford University, Mayfield, Mountain View, Los Altos, Santa Clara, College Park, San Jose, Milpitas, Edenvale, Los Gatos, and Saratoga.

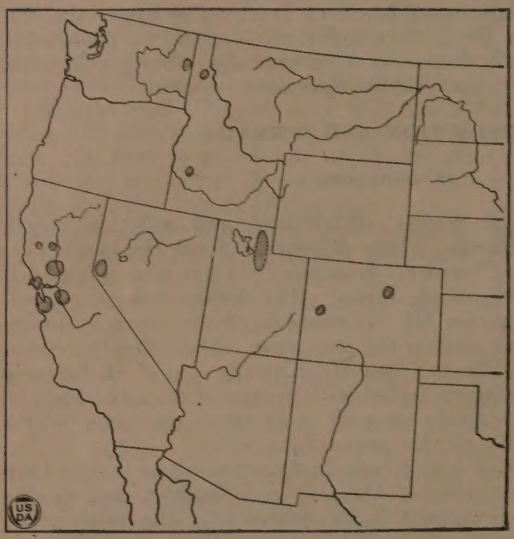

FIG. 1.—Known distribution of European elm scale in the West.

Additional localities in the United States and Canada have been recorded by Albert Hartzell (*8*).

SPREAD.

The elm scale was in all probability brought to America from Europe on young elm trees. The shipment of elm stock from infested nurseries to various parts of the United States has also been the cause of its being scattered over such a wide territory.

In these infested localities the scale has spread from tree to tree by several agencies. Birds, such as English sparrows, which are to be found in large numbers in the shade trees of almost any town, probably carry the young crawling scales for considerable distances on their feet. During the fall infested leaves drop to the ground and are blown for some distance by the wind. A certain percentage of these larvæ happen to find themselves at the base of an elm tree and crawl up to start a new infestation. The European elm scale has been seen spreading in this manner by both Professor Doten and the writer. The Argentine (*Iridomyrmex humilis* Mayr) and

other ants are known to transport scale insects from one tree to another in order to increase their food supply, and this method of transportation probably applies to this species as well as to others, since it is usually attended by a great many ants. Elms are nearly always planted so close that some of their branches interlace, enabling the larvæ to crawl at will from one tree to another. Thus it is not long before the European elm scale has thoroughly established itself upon most of the elms in a locality.

FIG. 2.—Adult females of European elm scale on elm branch. Slightly enlarged. (Wallace.)

INJURY.

Thousands of these scale insects sucking the plant juices from the leaves, twigs, and branches (figs. 2, 3) cause considerable injury to elm trees. Their effect upon the elm is shown by yellowing and premature dropping of the leaves, stunting of growth, and dying twigs, branches, and entire trees. Their injury is most apparent on young trees, which occasionally they kill. Mature trees are seldom killed.

A less serious trouble is the production of a considerable amount of honeydew, which covers the leaves, twigs, and branches, making them black and sticky. It also drops on the street and sidewalk, making the pavement slippery and dangerous to passing vehicles, besides having an unpleasant appearance and odor. Many disagreeable insects are attracted by the honeydew.

In some sections the American elm is reported as the favorite host of the European elm scale, while in other localities the English, Camperdown, or slippery elm is reported to be the favorite. The American and Camperdown elms seem to be preferred by it in California. Probably the degree of infestation depends upon the condition of the tree more than upon any other factor.

Trees which have been attacked for a number of years by this insect, if they do not die, finally seem to develop a certain amount of resistance to its injury. The history of this scale insect throughout North America has been much the same. It causes much concern to the owners of shade trees for a number of years after making its first appearance, and then seems slowly to lose its grip upon the trees until it causes a much smaller amount of damage. This is especially true in sections of the Eastern States and Canada, where less attention than formerly is now paid to this once dreaded insect.

FOOD PLANTS.

The recorded food plants of the European elm scale in the United States are English elm (*Ulmus campestris*), Scotch or Wych elm (*U. scabra*), European species, and white or American elm (*U. americana*), cork elm (*U. racemosa*), and slippery elm (*U. fulva*), American species, and their varieties. Probably all species of elms are subject to attack by this insect, although some have not yet been recorded as host to it.[4]

In 1895 Lintner, then State entomologist of New York, collected immature specimens of a scale insect on willow at Loudonville, N. Y., which were determined at that time as the European elm scale. This determination has since been corrected and those specimens have now been identified as a species of Eriococcus.

Signoret (*19, p. 21*), a French entomologist, has stated that he collected *Gossyparia spuria* on alder in France. Lindinger (*12, p. 54, 64, 122, 159, 338*), also a European entomologist, gives the following hosts in addition to elm: *Acer* sp., *Alnus* sp. (very probbly Signoret's record), *Corylus avellana*, *Fraxinus excelsior*, and *Viscum album*, all European records. From the fact that the European elm scale has not been found on any of these hosts in America, the writer is inclined to believe that some related species has been confused with it. At any rate there are no records of the European elm scale occurring on anything except elms in America. The writer has seen both alders and willows growing with their branches interlaced with those of infested elms, yet not a scale could be found on either of them. One specimen of *Zelkova acuminata*, which belongs to the elm family (Ulmaceae), has been seen growing near a large number of infested elms, but no infestation was apparent upon it.

DESCRIPTIONS.

EGG (PL. I, A).

Oval in outline, twice as long as wide, 0.36 by 0.19 millimeter. Color bright yellow; surface smooth and shiny. Eyes of larva visible as two black spots through the egg membrane.

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[4] Aside from the European elm scale the principal insect pests of the elm in the West are the carpenter worm, *Prionoxystus robiniae* Peck, which bores into the trunks and main limbs, often killing large branches and occasionally whole trees; an aphid, *Myzocallis ulmifolii* Monell, and a leafhopper, *Empoa ulmi* L., both of which suck the plant juice from the elm leaves and produce an abundance of honeydew. They are sometimes worse than the elm scale in this respect.

The elm leaf-beetle, *Galerucella luteola* Müll., is probably the worst enemy of the elm in the East, where it defolintes a great number of trees every year. It has also been introduced into the West, having been reported several years ago from Portland, Oreg. This has not yet become a serious pest in the West, but may in the near future.

LARVÆ.

First Stage (Pl. I, *B*).

Color bright yellow soon after hatching. Length 0.45 millimeter; width 0.19 millimeter. Of an elongate oval form, rounded anteriorly and tapering posteriorly to a pair of pointed processes, each bearing one long and several short setæ. Anal ring, occurring between these processes or lobes, with six setæ or hairs. Legs rather stout, with short tibiæ. Usual two pairs of thoracic spiracles present. A single row of blunt spines on the lateral margin of larva and a double row extending down the back, some reduced to rudiments. Also

Fig. 3.—Females of the European elm scale: *1*, Dead females in winter on corky elm (natural size); 2, living females in summer (enlarged about 4 diameters). (Doten.)

six extra spines on head and a number of very small spines on dorsum. Antennæ (Pl. III, *A*) rather stout and 6-segmented, sixth segment longest, fourth and fifth subequal and shortest, each segment bearing several hairs.

Second Stage (Pl. I, *C*).

Full-grown second-stage larva reddish brown in color. (In life of a gray appearance, due to the protruding wax.) Body oval in outline, rounded anteriorly and rather pointed posteriorly, about 1.1 millimeters long and 0.6 millimeter wide. Eyes situated near margin of body behind antennæ. Legs rather long and slender. Two pairs of thoracic spiracles present. Anal ring compound, bearing six setæ and situated between two prominent pointed anal lobes, each bearing a long slender spine on its tip, also several shorter spines on lobes. Entire dorsum covered with stout blunt spines and arranged more or less in two rows on each abdominal segment. Few small spines on venter.

In this stage one is able to distinguish the difference in sexes by the number of antennal segments. Antennæ of male larva 7-segmented, first segment broadest and seventh longest (Pl. III, *B*). Female larva with 6-segmented antennæ, quite similar to those of male, except that third and fourth segments have been replaced by one long segment, practically equalling the other two (Pl. III, *C*).

Both sexes have pores of the quinquelocular type (Pl. III, *E*) on the venter, but only the male larva has large circular pores on the dorsum and margin of the venter. These circular pores communicate with internal cylindrical ducts, which bear cup-shaped depressions on their inner ends (Pl. III, *G*), and are presumably the ones used in secreting the wax to form the pupal cocoon.

Adult or Third-Stage Female (Pl. I, *D*, *E*).

Female dull red-brown or green-brown after molting, elliptical in outline, later becoming oval and at the same time forming a waxy fringe about the margin of the body. Upon becoming engorged with eggs the adult female attains a length of 2.1 millimeters and a width of 1.3 millimeters. Antennæ (Pl. III, *D*) distinctly 7-segmented, third and fourth segments longest, fifth and sixth shortest. Previous writers have not always agreed upon the number of antennal segments possessed by the adult female. In some species the number is not constant; however, all western specimens examined possessed 7-segmented antennæ.

Usual coccid mouth parts and two pairs of thoracic spiracles present. Legs (Pl. III, *I*) rather long and slender. Anal ring compound, bearing eight setæ, and situated between two prominent lobes (Pl. III, *H*), each bearing three dorsal spines and one terminal and two ventral setæ, also a number of nodules which are particularly prominent and abundant on the inner surface. Entire dorsum covered with stout blunt spines, arranged as in preceding stage. Small slender spines and pores of quinquelocular type (Pl. III, *E*) on venter. Large circular pores (Pl. III, *G*) occur on dorsum and margin of body, being more plentiful on latter. These communicate with internal cylindrical ducts which bear cup-shaped depressions on their inner ends. There are also a few very small circular pores on the margin of the body communicating with small, slender, internal tubular ducts.

MALE PREPUPA (PL. II, A).

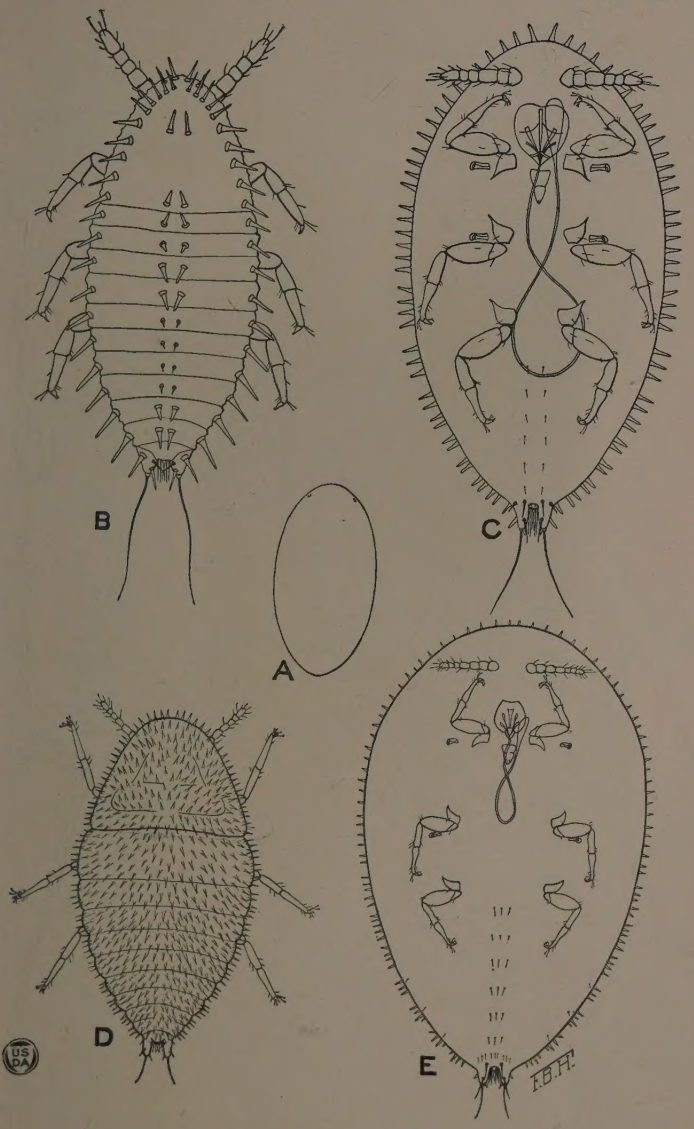
The second-stage male larva after forming a cocoon molts to a prepupa, which is the first dormant stage of the male. Color brownish red. Length 1 millimeter, and width about 0.5 millimeter. Oval in outline with head somewhat pointed. Apex of abdomen 3-lobed, a slender seta occurring on each outer lobe. Antennæ and legs not now long and slender, but short, thick, and immovable. Antennæ indistinctly 10-segmented. Very short wing pads present. No eyes visible and mouthparts lacking. Segmentation of body indistinct.

MALE PUPA (PL. II, B).

The second dormant stage of the male is also passed in the cocoon. This is a separate stage from the prepupa, a molt having taken place in between. Brownish red in color, oval in outline, slightly longer (1.1 millimeter), and more slender than prepupa. Top of head more rounded and tip of abdomen more distinctly three-lobed, central lobe larger and more pointed. Antennæ large and heavy, distinctly 10-segmented, reaching to base of wing pads. Wing pads larger, reaching to middle femora or beyond. Legs more distinctly segmented, longer and more slender, anterior pair folded over "face." Body more distinctly segmented; mouth parts lacking.

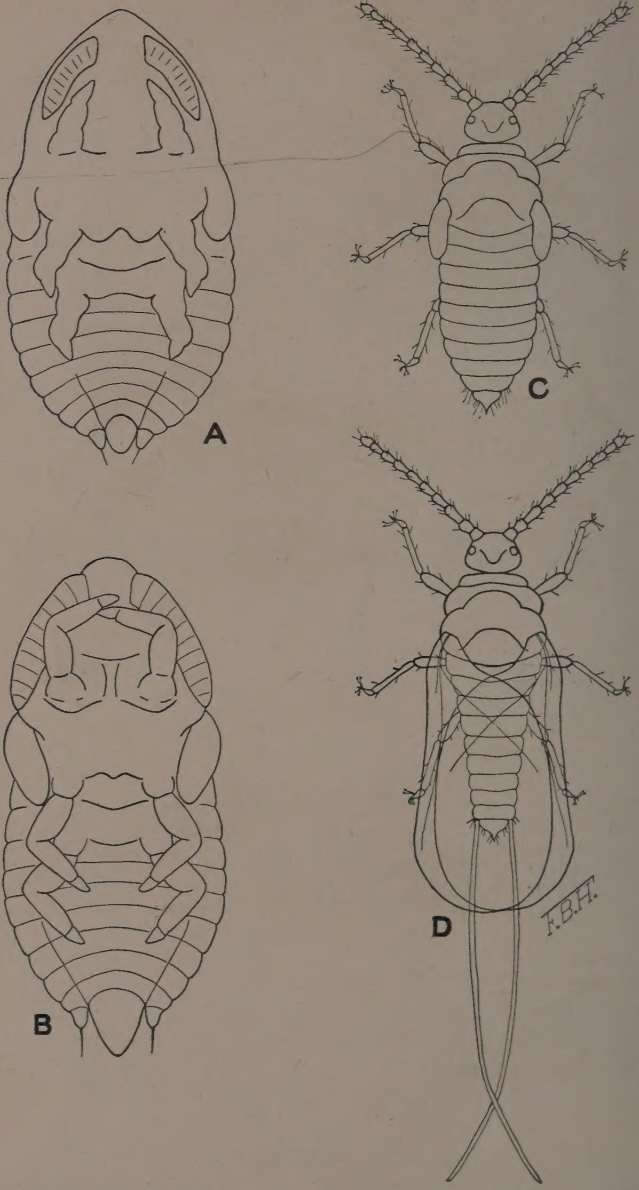
ADULT MALE.

Reddish brown in color and longer and more slender than pupa; 1.3 millimeters long and 0.4 millimeter wide. Head rounded, truncate between antennæ. Eyes black, with usual dorsal pair present and one ventral pair replacing mouth parts. Antennæ rather long and hairy, 10-segmented. Legs long and slender, tibia longer than femur. Caudal end 3-lobed, middle lobe large and pointed, bearing the genital organs; all three lobes bearing a number of setæ. Two large setæ on each outer lobe surrounded with a number



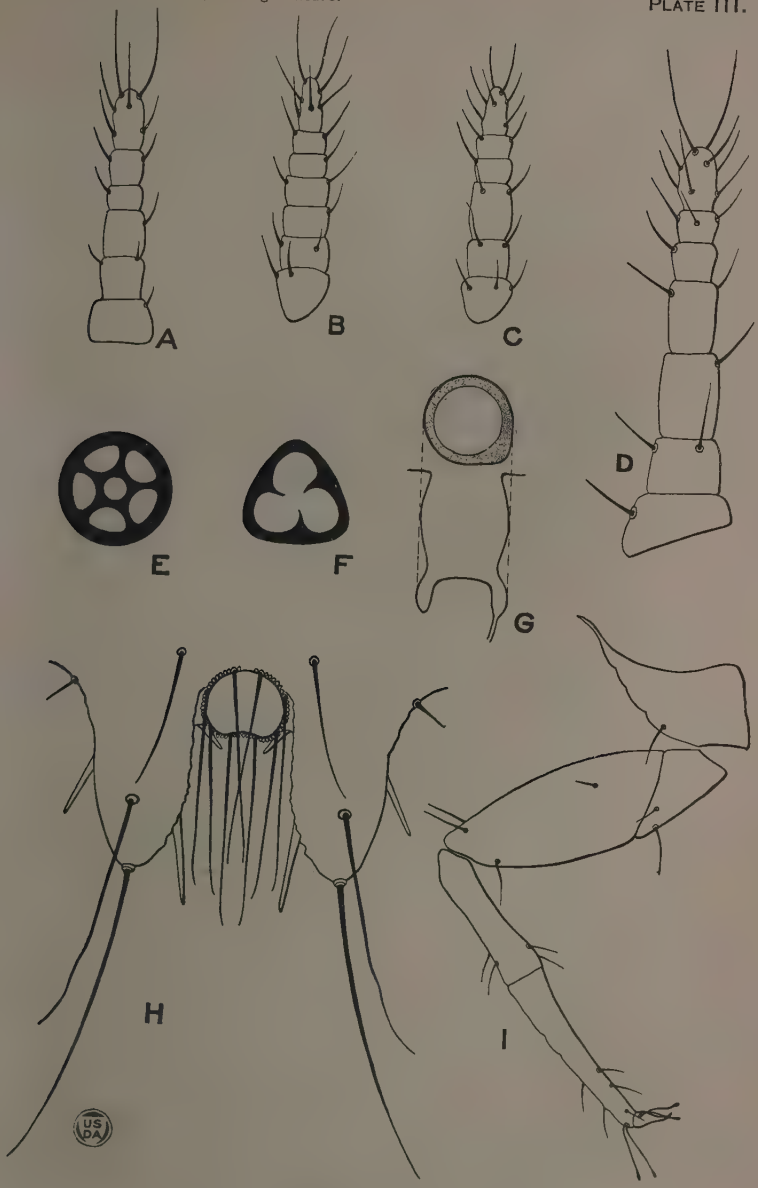
EUROPEAN ELM SCALE.

A, Egg. *B*, Dorsal view of first-stage larva. *C*, Ventral view of second-stage female larva. (Second-stage male larva is identical except for antennæ, which are 7-segmented.) *D*, Dorsal view of newly molted or virgin female. *E*, Ventral view of mature female.



EUROPEAN ELM SCALE.

A, Male prepupa. *B*, Male pupa. *C*, Wingless male adult. *D*, Winged male adult.



EUROPEAN ELM SCALE.

A, Antenna of first-stage larva. *B*, Antenna of second-stage male larva. *C*, Antenna of second-stage female larva. *D*, Antenna of adult female. *E*, Quinquelocular type of pore. *F*, Trilocular type of pore. *G*, Circular pore and cross-section of internal communicating duct. *H*, Ventral view of tip of abdomen of adult female. *I*, Leg of adult female.

EUROPEAN ELM SCALE.

A, Larvæ in winter partly concealed in crack in elm (× 10). *B*, Larvæ and male cocoons in early spring (× 16). (Doten.)

EUROPEAN ELM SCALE.

A, Larvæ in late summer along midrib on under surface of elm leaf (× 16). *B*, Male cocoons on elm bark (× 10). (Doten.)

EUROPEAN ELM SCALE.

1, Cocoon with protruding wings and anal filaments. *2* and *3*, Wingless males. *4*, Winged male. *5*, Cocoon, cast skins of larva and pupæ. (Doten.)

of trilocular pores (Pl. III, *F*). These are presumably what produce the wax filaments on some males.

There are two forms of the male, winged and wingless. The winged form (Pl. II, *D*) has full-sized wings folded over the dorsum when not in use, while the wingless form (Pl. II, *C*) has only short wing pads. The body of the wingless form is occasionally broader than that of the winged. There are, moreover, all grades between these two extremes, having all sizes of malformed wings. Two wax filaments, borne on the anal lobes, extend posteriorly and equal the length of the body in perfect males. These also vary in length, however, and may be present or entirely lacking on either the winged or wingless forms.

LIFE HISTORY AND HABITS.

In the spring after mating the female scales are found to contain a few eggs. By the time they have completed their semicocoons, however, they are well filled with eggs and have increased considerably in size.

OVIPOSITION.

The eggs remain in the body of the adult female until the embryos are about to hatch. As each embryo becomes fully developed the egg is expelled ventrally from near the tip of the abdomen. They are thus laid in a sort of pocket, being protected by the body of the mother and the surrounding fringe of wax.

Each female is capable of laying a large number of eggs. Adults examined on July 5, 1919, after having laid for some time, contained from 97 to 138 eggs. Professor Doten, of Nevada, reports having counted 60 to nearly 300 dead larvæ, which had been unable to escape from under different females. A drawing of the ovaries of an adult female by R. E. Snodgrass (*20, fig. 19*), would indicate a still larger number. He figures over 200 on one branch of the oviduct, making a total of approximately 425 eggs from one female. This would indicate that the rate of increase is quite large, yet not as great as that of many other scale insects.

The eggs are laid slowly, covering a considerable period of time, and only during the warm part of the day. One female observed laid 16 eggs in 5½ hours, or 1 about every 20 minutes. The larvæ hatch from these eggs about 40 minutes later and are ready to crawl away in another half hour.

It has several times been reported that the adult females give birth to living young. These misstatements are probably due to the fact that the eggs hatched very soon after deposition and were not seen by these observers.

LARVÆ.

Newly hatched larvæ are active and soon seek a place for attachment. Some attach themselves to twigs and branches, while a large majority of them migrate to the leaves, where they settle on both the upper and lower surfaces along the midribs, the pubescence of the leaf-veins affording them some protection. (Pl. V, *A*.) They remain in these positions until fall. By this time they are second-stage larvæ, having undergone their first molt about six weeks after hatching.

In the autumn, when the leaves begin to fade and fall, these larvæ move to more permanent places, locating in the crevices of the bark on the twigs and branches (Pl. IV, *A*) and clustering about the winter buds, where they spend the winter. Some of the larvæ fail to move from the leaves before these fall from the trees, and are carried considerable distances by the wind. Some of these die from starvation, while others crawl up the trunks of near-by trees to new feeding grounds.

The first-stage larvæ excrete very little wax, but the second-stage larvæ are well covered with sugary-appearing particles of it. This protects them in the winter from frost and rain and incidentally makes them immune to any mild form of spray material.

The larvæ remain in the second stage for from six to seven months, or from late summer to late winter or early spring. The male larvæ are the first to leave their winter quarters. In fact, some of them do not wait for winter to end, for on the first mild days in late January they begin to form their cocoons in which to pupate. They seem to be particularly fond of making their cocoons (Pl. IV, *B*) on dead twigs or branches, in the bark crevices, or near the crotches of living limbs. Their cocoons may even be found massed together in large white patches (Pl. V, *B*) on smooth exposed parts of the trunk or branches.

ACTIVITIES OF THE MALE.

The cocoon is made of waxy threads, secreted from the pores on the body of the larva. These are woven and twisted about until a definite covering has been formed. After completing the cocoon, which requires several days, the larva changes to a prepupa, which is the first dormant stage in the transformation from larva to adult. A definite molt takes place at this time, the cast skin being pushed out through a slit in the rear end of the cocoon.

A week or so later another molt occurs, this time to a true pupa, the second cast skin being pushed back out of the cocoon. (Pl. VI, *5*.) This stage occupies from one to two weeks, whereupon the pupa changes either to a winged (Pl. VI, *4*) or a wingless (Pl. VI, *2*, *3*) adult male. All the first pupæ to transform become wingless males, while all the last become winged males. During part of the intervening time both winged and wingless adults can be found, together with different forms between these two extremes. For instance, some males will have partly formed to nearly fully formed wings, while the wax anal filaments may vary from partly formed to full length or even be entirely lacking on either extreme. Temperature and humidity probably cause these variations. E. P. Felt (*7*), of New York, reports a definite period occurring between the appearance of the two forms of the adult male in the State. There is no such period in the West.

The wax filaments may be seen protruding from the cocoons for a day or so before the males emerge (Pl. VI, *1*), which they accomplish by backing out. They live only a few days, dying soon after they mate.

ACTIVITIES OF THE FEMALE.

The hibernating female larvæ begin their activities a little later than the male larvæ. In fact, most of them show no signs of activity until March, when they begin molting for the last time (Pl. IV, *B*). The white cast skins appear quite conspicuous on the bark. The newly molted or virgin females are smooth and of a dull brown or greenish-brown color. After mating they move about and settle down for the last time, most of them selecting the lower side of the larger limbs and branches. They soon take on a grayer appearance and begin to form waxy fringes of cotton or semicocoons about the margins of their bodies. By the middle of May they have about completed their semicocoons and are full grown, ready to begin oviposition. Egg laying lasts for several months, or until about the middle of August. During this time the females have slowly shriveled and die upon completing oviposition.

Soon after molting to the third stage the females begin excreting honeydew, and do not stop until egg laying is completed. This drops onto the foliage and the ground beneath, making the trees and ground very sticky. A black smut fungus grows in this sticky material giving the foliage a black appearance which can be seen for great distances.

SEASONAL HISTORY.

There is only one generation a year of the European elm scale. The second-stage male and female larvæ are the forms hibernating. Late in January in the milder climates a few of the male larvæ start forming cocoons in which to pupate. These become more abundant during February and March. Adult males begin emerging from their cocoons in February, becoming more abundant in March and April. A few of the last to transform emerge in May.

The hibernating female larvæ molt for the last time in March and April, whereupon they move to a proper place for the summer and mate. They soon begin to increase considerably in size, at the same time forming waxy semicocoons about their bodies. Egg laying starts the last of May or the first of June and continues through June, July, and part of August. Having completed oviposition the females shrivel and die.

The eggs hatch in less than an hour after being deposited and the tiny yellow larvæ crawl about, some settling on the twigs and branches, but most of them settling along the midribs of the leaves. About the middle of July the first of these larvæ molt for the first time, becoming reddish brown and later gray from the sugary particles of wax which are secreted over the back. The last of the yellow larvæ molt early in September. These second-stage brown or gray larvæ are the overwintering forms, and are found mostly clustered about the winter buds and in the rough areas of the twigs and branches.

A definite relationship has been observed between the activity of the European elm scale and its host. As the events in the life cycle

of the elm are more evident than those of the scale insect, it is well to indicate this relationship, especially since the time of application of control measures often depends upon both. The tree and the insect awaken from hibernation at the same time. The females undergo their last molt while the fruit is forming on the tree. Most of them have attained a large size and are secreting their semicocoons when the fruit begins to fall from the tree. The semicocoons are completed by the time most of the leaves are full grown, and egg laying starts two or three weeks later. The second-stage larvæ migrate from the leaves back to the twigs and branches when the tree sap becomes sluggish and the leaves begin to yellow and fall.

NATURAL ENEMIES.

The insect enemies of the European elm scale are very scarce and play but a small part in its control. The first and only record of the rearing of a parasite from this scale in the United States was in 1898 by R. A. Cooley (*1*), who reared half a dozen specimens at Concord, Mass. These have never been described, but remain under the manuscript name of *Coccophagus gossypariae* Howard. The writer endeavored a number of times to obtain parasites from western material, but was unsuccessful. Either there are none in the West or they are so scarce that they do not figure in the control of this scale insect.

The predatory enemies of the European elm scale are somewhat more numerous, but even they can not be considered as important agencies in its control. The twice-stabbed lady-beetle, *Chilocorus bivulnerus* Mulsant, is the most common enemy of the European elm scale. Essig (*6, p. 119–120*) mentions that Dr. A. J. Cook reported this beetle as preying upon the scale insect at San Rafael, Calif. The writer also has observed beetles of this species feeding upon the body contents of adult females.

Both larvæ and beetles of the black lady-beetle, *Rhizobius ventralis* Erichson, fed upon this scale insect when in captivity, and in all probability feed upon it when free, as it is usually found abundant upon scale-infested trees. The common black-spotted red lady-beetle, *Hippodamia convergens* Guérin, and its variety, *ambigua* LeConte, have been found rather plentiful upon infested trees and probably prey upon this scale insect, yet none have been observed actually feeding upon it.

The green lacewing *Chrysopa californica* Coquillett has also been reared upon the European elm scale and is found to some extent upon infested elms. No other insect enemies of this pest have been observed.

CONTROL EXPERIMENTS.

TABLE 1.—*Experiments performed upon the European elm scale.*

No.	Date.	Spray material.	Dilution.	Trees.	Scales killed.	Remarks.
					Per cent.	
1	Apr. 15, 1918	Water	100 to 160 pounds pressure.	191	85	Used fire engine and hose, large trees.
2	Apr. 19, 1918	do	50 pounds pressure.	2	95	Used garden hose and nozzle, small trees.
3	Apr. 26, 1918	do	do	1	80	Used garden hose, extension rod, and 12-foot platform, medium-sized tree.
4	May 14, 1919	do	do	2	97	Used garden hose, small tree.
5	Dec. 3, 1918	Distillate emulsion	1 to 5	3	60	Hibernating larvæ.
6	Mar. 5, 1919	Crude-oil emulsion	do	3	60	Do.
7	do	Distillate emulsion	1 to 4	8	60	Do.
8	do	Kerosene emulsion	1 to 4.5	3	25	Do.
9	do	Distillate emulsion	1 to 4	1	65	Do.
10	Apr. 12, 1919	do	do	3	60	Trees in leaf, slight burning.
11	Jan. 19, 1920	Crude-oil emulsion	1 to 5	4	60	Hibernating larvæ.
12	do	Distillate emulsion	1 to 4	3	20	Do.
13	do	do	1 to 3	3	20	Do.
14	Apr. 12, 1919	Fish-oil soap	1 pound to 7 gallons.	3	5	Trees in leaf, no burning, young females.
15	do	Lime-sulphur	1 to 9	3	20	Do.
16	Dec. 3, 1918	Miscible oil, 33°	1 to 12	5	10	Hibernating larvæ.
17	Mar. 5, 1919	Miscible oil, 28°	1 to 7	3	99	Do.
18	Jan. 19, 1920	do	do	4	98	Do.
19	do	do	1 to 9	2	100	Do.
20	Mar. 4, 1920	Miscible oil, 33°	do	4	30	Do.
21	do	do	1 to 12	3	20	Do.
22	do	Miscible oil, 28°	1 to 9	3	97	Do.
23	do	do	1 to 12	4	99	Do.
24	Apr. 19, 1920	do	1 to 15	2	40	Young females.
25	do	do	do	2	95	Do.
26	do	do	1 to 12	1	98	Do.

In experiment No. 1 the trees were large, in No. 3 the tree was medium-sized, and in all the others the trees were small and could be sprayed from the ground with an ordinary bucket pump. This was the apparatus used, except in the first four experiments, where water was applied. All but one of the experiments were performed at San Jose, Calif., upon the elms growing on the normal school grounds.

WASHING EXPERIMENTS.

Washing the scale from the elm trees with a solid stream of water was experimented with, since fairly good results had been obtained in this manner by Prof. S. B. Doten, of Nevada (*3*, *4*). In fact, his results seemed more satisfactory than spraying with a lime-sulphur solution or kerosene emulsion.

In preliminary experiments, it was found that the best nozzle that could be obtained for the usual pressure of 50 pounds to the square inch on the garden hose was one with a 3/16-inch outlet and a long taper.

On small trees this equipment was used to good advantage to wash the mature scale insects from their resting places. (Fig. 4.) All limbs were within easy reach and the trees so small that a thorough washing was possible. The results obtained were highly satisfactory and the trees remained clean until reinfested in the fall.

On medium-sized trees the same apparatus was used, with the addition of a 12-foot platform and a 7 or 8 foot extension rod. This proved to be too tedious and was only moderately successful even when done carefully.

FIG. 4.—Washing young elm tree with garden hose and nozzle to remove the European elm scale.

On large trees it was necessary to have a greater pressure and volume of water in order to obtain satisfactory results. This was obtained by using a fire engine, supplemented with 1,000 feet of 2½-inch hose, a short tapering nozzle with a circular ⅞-inch opening, and a stand to facilitate holding the nozzle. (Fig. 5.)

It was possible to use a pressure of 160 pounds without doing any damage to the foliage already out. It proved beneficial, in fact, by removing all dead twigs and branches and incidentally giving the trees and lawns a good irrigating.

The crew consisted of one foreman, one engineer, and three hosemen, this number being necessary in order to move the heavy hose without delay.

With this apparatus and crew 191 large trees were satisfactorily washed in six days at an approximate cost of $1.20 per tree. During all the following summer the trees remained very clean, one or two showing evidence of the presence of a few scale insects by a slight drip. The writer estimated that about 85 per cent of the scales had been removed. One year later, however, the trees were again infested rather badly, owing partly to the remaining 15 per cent and to a reinfestation from the surrounding well-infested trees.

The results of these washing experiments have been previously reported in considerable detail (*9*).

SPRAYING EXPERIMENTS.

Sprays consisting of distillate emulsion, kerosene emulsion, or crude-oil emulsion at strengths varying from 3 to 5 parts water to 1 part emulsion proved entirely unsatisfactory for the control of the European elm scale, only 20 to 60 per cent of them being killed. A solution of 1 pound of fish-oil soap and 7 gallons of water was used upon some molting females but was completely unsuccessful. Although other experimenters have reported fair results from the use of lime-sulphur, the writer's results with it were unsatisfactory, practically none of the insects being killed. This material can not be used in shade-tree work to any great extent because the sulphur in it combines with the paint on buildings and turns it black.

FIG. 5.—Washing large elm trees with water from fire engine to remove the European elm scale.

The best results were obtained from miscible-oil sprays. Those containing 28° Baumé oil were found to be very satisfactory, whereas those containing 33° gave very poor results. The former were efficient at the proportions of 1 part oil to 9 and 12 parts water, and certain brands of them at the greater dilution of 1 to 15 parts water. Miscible oil 28°, 1 part to 12 parts water, is the material to be recommended.

RECOMMENDATIONS FOR CONTROL.

Either of two materials is recommended for the control of this insect, a solid stream of water or a miscible oil spray. The garden hose and nozzle may be used to good advantage where a few small

trees need to be rid of this pest. The ordinary pressure of water from the hydrant will remove the insects at a distance of 10 or 12 feet. Each limb and twig must be hit with a solid stream of water from at least two directions. The use of a fire engine and equipment is quite satisfactory on trees over 20 feet high. It probably does not produce as good results as when a high-capacity spray outfit is used, but when the former is available and the latter is not, it is recommended for large trees. It is cheaper than spraying and can not damage the elms.

All washing should be done in the spring just before the leaves appear on the trees, usually about the middle of April. The fruits

FIG. 6.—Spraying large elms with high-power outfit to remove the European elm scale.

or small winged seeds begin falling from the trees about a week before the leaves appear, thus providing a warning that the washing should be done soon. At this time the female scales are large, being full of eggs, and are easily washed from the trees. This washing could be done at any time until egg laying begins, five or six weeks later, were it not for the presence of the foliage, which impedes the force of the stream. Thus to insure success in washing there must be a solid, forceful stream of water, and it must be used at the proper time.

A more satisfactory method of control is the use of miscible oil containing 23° to 28° Baumé oil, which can be obtained from dealers under various trade names. This should be used in the following proportions:

Miscible oil (23° to 28° Baumé)	1 gallon or 16 gallons.
Water	12 gallons or 184 gallons.

It is mixed by first pouring the requisite amount of oil into the spray bucket, barrel, or tank to be used and then adding a small amount of water. With considerable agitation this will become light-colored and of a creamy consistency, whereupon more water may be added, and finally all the water, in the meantime agitating thoroughly. This may then be applied with any sort of spray outfit, providing the apparatus has power enough to send a spray to the tree tops.

The bucket or barrel pump will do very well for small trees, the ordinary orchard power outfit for trees up to 40 feet in height, and a high-power apparatus for trees above this height. (Fig. 6.) A pump registering a pressure of at least 300 pounds with a capacity of 12 to 15 gallons or more per minute is necessary to reach trees 60 to 90 feet high, which is often the height of mature elms. A spray gun or solid-stream Worthley nozzle is necessary to force the spray to the tops of the trees from the ground. The use of a smaller outfit and ladders is not to be recommended, on account of extra cost and unsatisfactory results.

Large trees require from 30 to 50 gallons of mixture, costing from 3 to 4 cents per diluted gallon for the material and 1½ to 2½ cents per gallon to apply it.

Every branch and twig should be covered, but too much spray should not be allowed to settle about the base of the tree, as it might injure the roots. No damage to elm trees or lawns has been noted, however.

The spraying should be done in the winter up to the time the buds begin to open in the spring. Probably a weaker spray could be used on the young forms in the late summer but this would be about as expensive, for nearly twice the amount of material would be required to cover each tree on account of the foliage, and it would be much less satisfactory since all parts, particularly the underside of the leaves, which are the most heavily infested, could not be thoroughly covered.

If properly done, spraying should not be necessary every year, except upon young trees, which seem to become reinfested easily when near unsprayed large trees. Extermination, of course, is not to be hoped for, but it is possible to kill a sufficiently high percentage of the insects to prevent their appearance in large numbers the following season.

SUMMARY.

The European elm scale was introduced into this country about 1884 from Europe and was first found at Rye, N. Y. From there it has spread until it is now located in 27 States and the District of Columbia. Although more widespread in the East, the injury to

trees is not as great as in the West. This insect infests only elms, doing damage particularly to young trees, but killing twigs and branches of the older ones. It causes the leaves to turn yellow and drop early, besides making foliage and ground black and sticky from its secretion of honeydew.

The first-stage larva is a small, yellowish, oval object about 0.5 millimeters long. The second-stage larva is over twice as long as the first, and is reddish brown, but appearing gray from the waxy coat on its back. The adult female is large and oval, about 2 millimeters long, and of a dull red-brown or green-brown color, surrounded by a white cottony fringe of wax.

The second-stage larvæ hibernate in the bark crevices and about the winter buds. In early spring the male larvæ form cocoons and transform in them to adults. By this time the female larvæ have molted and seek a sheltered place on the underside of the limbs and branches. After mating they form a waxy fringe about their bodies and in late spring or early summer begin to deposit their eggs. This they continue to do throughout the summer, and upon completing oviposition they shrivel and die. The larvæ hatch very soon from these eggs and crawl to the midribs of the leaves or in some case remain in the bark crevices. All molt to the second stage. Those on the leaves move in the fall to more premanent winter quarters on the twigs and about the buds, where they remain until activity begins again in the early spring.

Several lady-beetles feed upon the European elm scale but are not plentiful enough to be considered as important enemies. A number of sprays have been experimented with, but only washing in the spring with a solid stream of water and spraying in the winter with a solution of 23° to 28° Baumé miscible oil, 1 part oil to 12 parts water, have proved effective in the control of this pest.

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